Project 4
Measurement of Selenium Flux

CH2M HILL TASK ORDER NO. 5. SUBCONTRACT WITH:	University of Utah & United State Geological Survey (USGS)
PRINCIPAL INVESTIGATORS:	Dr. William Johnson/University of Utah, Dr. David Naftz/USGS
CONTRACT VALUE:	$303,700
SCHEDULE:	April 1, 2006 through February 28, 2008 (elapsed time: 23 months)

Project Objective

The objective of this project is to perform measurements necessary to support the development of a selenium budget for the Great Salt Lake. The project is comprised of three specific tasks that address four high priority questions identified during development of the conceptual model for selenium cycling in the Great Salt Lake. Please see Data Quality Objectives for Project 4 for further detail.

High priority questions:

1. Are volatilization and ebullition significant release mechanisms for selenium from the Great Salt Lake? Volatilization/vaporization may be the only major mechanism of permanent selenium removal from the system (other than brine shrimp harvest). Oceans are a major source of selenium vapor (as demonstrated in publications referenced in Conceptual Model). Deep brine samples show loss upon opening (Round Robin Study).

2. What is the rate of permanent sequestration of selenium via sedimentation? Sedimentation may be the major effective mechanism of selenium removal from the system.

3. Do transient suspension events re-suspend and re-solubilize selenium into the water column to an extent that has biological significance? Temporal variations in brine shrimp concentrations are observed and need to be understood. Are these temporal changes related to transient events or changes in the phytoplankton community?

4. Do lake level rises re-introduce selenium into the water column to an extent that has biological significance? Based on the area/volume curve for Great Salt Lake just released by the USGS (Baskin, 2005), a 0.5-foot increase in lake from 4197.0 to 4197.5 (current lake level in feet above sea level) submerges 7,740 acres of previously dry sediment. Understanding the selenium content of these exposed sediments is also useful for wind suspension concerns for air quality.

These questions cannot be answered via a literature review due to the fact that these processes in the Great Salt Lake have not been heavily investigated. Furthermore, the existing literature for other systems does not address a system of the size, salinity, vertical and spatial heterogeneity, and temporal variability as represented in the Great Salt Lake. The execution of Project 4 requires well-conceived field measurements that are not widely available, but which are available via the combination of university, federal, and private analytical capabilities as pooled in the CWECS-CH2M HILL alliance.

Baskin, R.L., 2005, Calculation of area and volume for the south part of Great Salt Lake, Utah: U.S. Geological Survey Open-File Report 2005-1327, 6 p.

General Assumptions

1. The estimated level of effort, number of samples, and costs are documented in Contract.
2. Prior to executing Project 4, a workplan and the associated components (i.e., budget, required protocols, etc.) as well as Data Quality Objectives will be prepared and reviewed by the Great Salt Lake (GSL) Science Panel, Utah Division of Environmental Quality, technical advisors, and GSL Steering Committee. Principal investigators will participate in study team meetings and conference callson an as-needed basis.
3. No additional samples will be collected or analyzed for mercury.
4. All work will follow UDWQ's Quality Assurance Plan protocol. Samples will be shipped to the laboratory selected by UDWQ following required protocol. Cost of laboratory analysis of sediment completed by UDWQ's laboratory is not included in this scope of work. The parallel FFF-ICP- MS laboratory analysis of sediment samples will be completed at the University of Utah's laboratory per approved protocol. Costs of completing the analysis of these samples are included in Contract.
5. Reports described below may be consolidated as appropriate and approved by UDWQ.
6. All necessary clearances/permits to complete the work specified herein will be acquired prior to and maintained for the length of the work. All access will be properly coordinated and permission obtained.
7. Safety is of the essence. Health & safety protocol will be identified prior to field work begins and followed.

Scope of Work

Task 1 – Measure Vapor Flux

Objective

Selenium vapor flux can occur via volatilization (transfer of dissolved volatile selenium in water to the vapor phase) and ebullition (formation of bubbles in the water of which vapor selenium may be a major or minor component). The mass transfer via volatilization would be expected to be low per square meter of the lake surface, because diffusion of volatile selenium species to the lake surface through the water column would be slow. However, the flux of volatile selenium to the lake surface will increase if convection occurs, for example via mixing of the water column by wind; furthermore, this volatilization flux may occur across the entire area of the lake. In contrast, the mass transfer per square meter via ebullition can be very rapid due to the buoyancy of bubbles. However, ebullition may not be widespread spatially, and it may be subject to greater temporal variability than volatilization.

Task Schedule

	CY 2006				CY 2007				CY 2008				
Task 1	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**
Preparation for dissolved gas surveys													
Dissolved gas pressure surveys													
Collection and analysis of gas samples for volatile selenium compounds													
Preparation of maps showing areas of potential selenium flux to the atmosphere													
Estimation of annual selenium flux to the atmosphere from GSL													

Task 1.1 Volatilization

1.1.1 Data Collection/Evaluation

Diffusion samplers (3 locations, 3 depths at each location, 6 time periods). Passive diffusion samplers will be deployed to collect selenium vapor in equilibrium with dissolved volatile selenium in the water column. Samples will be collected from three locations and at three depths to determine the near surface concentration gradient for dissolved volatile selenium. The strings of diffusion samples will be deployed at each site for a period of 24 to 48 hours. The samplers will be anchored with a cinder block and marked with buoy for sample retrieval. Upon retrieval, each sampler will be cold welded in the field within 30 seconds of retrieval. The flux of volatile selenium across the lake-atmosphere interface will be estimated using a modified Henry's constant accounting for salinity (via Setechenov coefficients). The flux rate to the surface will be estimated via the near-surface concentration gradient for dissolved volatile selenium. Passive diffusion samplers are used extensively for dissolved gas characterization in groundwater and lake water. The possibility that methyl selenides will partition to the membrane will be examined using standards (as described below). Otherwise we will try sparging a liter of water with He to recover volatile Se.

1.1.2 Quality assurance.

Diffusion samplers will be checked for selenium contamination in copper tubing via equilibration with pure water. Dissolved volatile selenium interaction with the diffusion membrane and vapor selenium interaction with the stainless steel tubing of the quadrupole mass spectrometer will be checked using standards for dimethylselenide and dimethyldiselenide. Dimethylselenide and dimethyldiselenide are commercially available. Each passive diffusion sampler is designed to collect a duplicate sample for additional QA during chemical analysis. Duplicate samples will be collected for this purpose.

Quality assurance criteria will be developed during implementation of the analytical method. However, sensitivity of the analysis can at present be addressed qualitatively on the basis of comparison to dissolved krypton concentrations, which are routinely analyzed using this instrument for the purpose of groundwater age dating. The quadrupole mass spectrometer routinely measures dissolved Kr concentrations in the range of 0.001 picomoles/L after removal of other gases (N_2, O_2, CO_2, and Ar).

One estuary study of dissolved dimethylselenide reported concentrations ranging 0.8 to 6.3 picomoles/L (Pecheyran et al., 1998). The corresponding equilibrium vapor selenium concentrations will be estimated using the dimensionless Henry's constant for dimethylselenide in pure water, which is 0.032 at 4 °C (Guo et al., 2000). The resulting equilibrium vapor selenium concentrations range between 0.025 and 0.19 picomoles/L, which are factors of 20 to 200 times greater than typical krypton vapor concentrations. The estimated equilibrium vapor selenium concentration is conservative since the actual Henry's constant would be greater due to salting out.

The analysis requires the removal of other gases in the sample (e.g. , N_2, O_2, and Ar) via reversible sorption of the Se onto charcoal at a specific temperature. The quadrupole mass spectrometer has custom cold trap that can be held at any temperature between +50 °C and -180 °C and a commercial cold trap that operates between -20 °C and -263 °C). The other gases are pumped away while Se is held in the trap. The Se is then desorbed (by warming the cold trap) into the mass spectrometer. The system is automated such that after method development and testing, the entire process is completed by the controlling computer.

This sort of strategy was previously employed by Pecheyran et al. (1998) who "cryofocused" vapor selenium as follows. The purged gases were dried into a cold water trap (-20 °C) and finally trapped into a packed chromatographic column immersed in liquid nitrogen (-196 °C). The cold water trap was a simple u-shaped glass tube (2 cm i.d., 20 cm length) at -20 °C in a mixture of acetone-dry ice, with glass tips grafted to interior to enhance temperature exchange. They demonstrate the effect of temperature and helium purge flow rate on this drying process. The chromatographic column was a u-shaped silanized glass tube (6 mm i.d., 13 cm length) packed with Chromosorb W-HP 60-80 mesh coated with 10% Supelco SP2100. Selective desorption and separation of the volatile selenium species was acheived by gentle warming of the column using a helium flow rate of 0.1 L/min.

If needed, the contents of the cold trap for the quadrupole mass spectrometer will be replaced with the same materials used by Pecheyran et al. (1998).

Henry’s constants in this system will be directly determined via batch equilibration experiments in closed containers with headspace. The vapor concentration will be determined as described above, whereas the dissolved volatile selenium concentration will be measured as described above following sparging with He after evacuation of the headspace.

Task 1.2 Ebullition

Task 1.2.1 Total dissolved gas surveys (20 locations, 5 depths, six time periods beginning in June 2006 and ending in May 2007) will be conducted from a boat using a total dissolved gas probe deployed from a Hydrolab minimonitor. See figure 1 for sample locations. The total dissolved gas pressure will be compared to hydrostatic pressure (using a pressure transducer), and a positive or negative potential for gas flux will be determined. Spatial (e.g., horizontal and vertical) and temporal variation will be addressed in this system due to the relatively rapid equilibration of diffusion samplers with the water column. The Hydrolab minimonitor can also monitor total dissolved gases during wind events to determine the influence of these events on dissolved gas concentrations.

Task 1.2.2 In the event that total gas pressure exceeds hydrostatic, this will be a strong indication of upward gas flux in the Great Salt Lake system. In this event, a floating flux chamber will be deployed, after consultation with project team, to collect vapor emitted from the lake surface. The vapor (sampled as a time series) will be analyzed using the methods described above. The time series of vapor selenium concentrations will support estimation of an ebullition flux of selenium from the lake. These results will be combined with the results from the total dissolved gas surveys to estimate the annual flux of selenium being removed from the South Arm of GSL. The gas modeling capabilities of the USGS geochemical modeling software PHREEQC (Parkhurst and Appelo, 1999) will be used to simulate selenium ebullition under a variety of hydrologic and geochemical conditions. **This task (1.2.2) is not included in this scope of work**. If there is a strong indication of an upward gas flux, a separate scope of work and cost will be identified, discussed and incorporated in a separate change order to this contract.

Task 1.3 Opportunity sediment samples

While the boat is stationary for total dissolved gas measurements it will be possible to grab sediment samples for analysis for total Se and total organic carbon analysis. Multiple samples will be obtained and composited to represent each dissolved gas sampling location. The number of replicate samples will be balanced against the time spent beyond which the dissolved gas probe equilibration occurs. That is, rapid equilibration of the dissolved gas probe allows greater numbers of dissolved gas stations, but lesser numbers of composited sub-samples. These two needs will be balanced. Sediment samples (20-40) will be collected and shipped to a laboratory selected by UDWQ following required protocol.

Deliverables:

1. Sediment samples, including QA/QC samples, as listed in Contract, delivered to laboratory selected by UDWQ per sampling protocol (completed by November 30, 2006).
2. Vapor selenium concentrations from diffusion samplers with analysis via cryo-focusing and quadrupole mass spectrometry in vaccum (completed by 03/31/07).
3. Progress updates in the form of data graphs and statistical summaries will be provided to UDWQ or designee upon demand. Data requests cannot exceed 2 requests per 12-month study period.
4. Preliminary report on estimate of selenium flux to atmosphere via vaporization and volatilization. Report will provide a preliminary evaluation of the potential for ebullition flux via total dissolved gas pressure collected during six dissolved gas surveys. The objective of this report is to provide the Science Panel with available information gathered in 2006. Preliminary report will be completed by 03/31/2007.
5. Final report on estimate of selenium flux to atmosphere via vaporization and volatilization and potential for ebullition vlux via total dissolved gas pressure collected

during six dissolved gas surveys. Report will include seasonal maps showing areas of potential selenium vapor flux in open water of GSL and estimated annual selenium loss to the atmosphere from this process. Report will document activities, methods, assumptions, data, recommendations, and conclusions completed as part of this task (completed by 5/31/2007).

References

Pecheyran C., Amouroux D., and Donard O.F.X., 1998, Field determination of volatile selenium species at ultra trace levels in environmental waters by on-line purging, cryofocusing and detection by atomic fluorescence spectroscopy, JAAS, 13, 615-621

Guo L., Jury W.A., Frankenberger W.T., 2000, Measurement of the Henry's constant of dimethyl selenide as a function of temperature, Journal of Environmental Quality 29 (5): 1715-1717 SEP-OCT.

Parkhurst, D.L., Appelo, C.A.J., 1999, User's Guide to PHREEQC (Version 2)--A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259.

Task 2 – Measure Particle Flux

Objective

The goal of this task is to measure selenium fluxes to and from Littoral Sediment and Anoxic Sediment. As well, selenium concentration in the Deep Brine Layer will be determined. The selenium flux to sediment will be determined via collection of settling aggregated macromolecules and particulates in sediment traps. The selenium flux to sediment will be compared to selenium concentrations in accumulated sediments (Task 3). The flux from sediment during re-suspension events will be estimated using data from thermistor strings augmented with a turbidimeter. The potential export of selenium from the Deep Brine Layer to the Shallow Layer will be examined via characterization of dissolved, macromolecular, and particulate selenium burdens in the Deep Brine Layer.

Total selenium burden in the settling phases and in the Deep Brine Layer will be determined via digestion followed by hydride generation (HG) combined with atomic absorption (AA) or another spectrophotometric technique. Although total selenium concentrations provide a well-accepted methodology and a gross measure of selenium flux, they do not provide information regarding the propensity for chemical change during burial and re-suspension.

To address the propensity for chemical change during burial and re-suspension, the settling phase must be characterized in terms of makeup (e.g. biological versus mineral), size (molecular to particulate), and the selenium burden must be apportioned among these various molecular to particulate fractions in the settling phase. Comparison to accumulated sediment would indicate which chemical changes are important during burial and resuspension. This characterization would be laborious using commonly available methodologies. However, the existence of field flow fractionation (FFF) combined with inductively coupled plasma mass spectrometry (ICP-MS) allows this characterization to be performed within a single analysis. Furthermore, the ability of ICP to accept particles up to approximately 10 µm in size allows this characterization to address the bulk of the macromolecular to particulate phase via direct analysis of the sample, thereby eliminating the need for additional filtration or digestion treatments that weaken the power of the analysis and introduce the potential for sample contamination. Finally, field flow fractionation allows the removal of salts that interfere with analyses for determination of selenium via ICP-MS.

Task Schedule

	CY 2006			CY 2007			
Task 2	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
Preparation for thermistor deployment							
Thermistor deployment and retrieval cycles							
Deployment of turbidity meter							
Collection of continuous turbidity data							
Deploy sediment traps							
Collection and analysis of sediment trap samples (monthly)							
Collection of water-column samples for particulate selenium analysis							
Data analysis and estimate of annual downward particulate selenium flux							
Data analysis and qualitative estimate of selenium input from storm suspension of particulates							

Task 2.1 Downward Flux

Task 2.1.1 Sediment traps (2 locations—one below the Deep Brine Layer, and one directly below the Shallow Layer. Sediment traps will be deployed and collected monthly for 12 months).

Task 2.1.2 Water column samples (8 locations, 2 depths each, collect samples monthly for 12 months) at location concurrent with sediment traps. Concurrent with sample collection, detailed water column profiles (pH, temperature, turbidity, specific conductance, dissolved oxygen, and oxidation/reduction potential) will be conducted with a water-quality minimonitor.

- Complete laboratory analysis of sediment samples
- Fractionate molecular to particulate phases using FFF-ICP-MS (with collision cell) verify with HG-AA
- Determine mass and composition of each size fraction
- Determine selenium burden on each size fraction

FFF is a valuable analytical technology that size fractionates molecules to particulates according to their diffusion rates in water. The instrument employs longitudinal flow to advect the analyte toward a collection port. The longitudinal flow is bounded on one side via a membrane chosen to disallow passage of the molecular to particulate phases carrying selenium. Cross-flow is established to force the selenium-carrying molecular-to-particulate phase proximal to the membrane. Salts pass through the membrane and are thereby eliminated from the sample. Since diffusion rates are inversely correlated to size, the smaller components of the molecular-to-particulate phase diffuse away from the membrane toward greater fluid velocities in the longitudinal field. The molecular-to-particulate phase is thereby fractionated such that smaller components (molecules) enter collection ports before larger components (e.g. particulates). On-line UV absorbance and fluorescence spectrophotometers determine the organic versus mineral makeup of the component, and immediate downstream analysis via collision cell-ICP-MS provides elemental information including selenium.

FFF-ICP-MS results will be compared to commonly used techniques to examine sediment Se concentrations, e.g. HG-AA (or another technique). If the methods disagree with respect to total Se concentration, then the commonly-used technique will be considered accurate. However, if it can be proven that the FFF-ICP-MS yields greater accuracy, the FFF-ICP-MS technique will be considered most accurate.

Task 2.1.4 Estimate downward flux from size-burden relationship

Task 2.2 Upward Flux

Task 2.2.1 Deploy turbidimeter (1 location, continuous measurement, data retrieved monthly for 12 months) and supplement with thermistor strings (3 locations, 6 depths, continuous measurement, data retrieved semi-monthly for 12 months) for determination of mixing via temperature gradient.

Due to the relatively large temperature difference between the water in the Deep Brine and Upper Brine Layers, continuous temperature measurements in the water column will facilitate monitoring of transient mixing events between the two layers. Two of the three thermistor strings containing 6 temperature logging thermistors (Hobos) will be placed in regions of GSL containing the Deep Brine Layer. The Hobos will be programmed to collect water temperature data at 15-min intervals over the one-year sampling period. Temperature data will be retrieved from each Hobo seasonally to prevent data loss. In combination with one of the thermistor strings, a turbidimeter will be deployed directly above the deep brine layer at a depth of approximately 6 m below the water suface. Turbidity measurements will be made at 15-min intervals over the one-year sampling period to assess the timing and duration of sediment resuspension during transient storm events on GSL.

Task 2.2.2 Water column sampling at the location of the turbidimeter after turbulence event to measure potential redistribution of selenium. Whenever possible, water column samples (dissolved and total selenium) will be collected immediately after selected storm events (two to three) at the location of the turbidimeter to directly measure the upward flux of selenium from the Deep Brine Layer.

Task 2.2.3 Estimate upward flux of selenium.

The distribution of selenium in various particulate size fractions will be used in combination with the continuous turbidity and temperature measurements to estimate the amount and significance of upward flux of selenium from sediments beneath the deep brine layer.

Deliverables:

1. Sediment samples, including QA/QC samples, delivered to laboratory selected by UDWQ per sampling protocol. Water column profile data for one year sampling period.
2. FFF-ICP-MS results for sediment and water samples as listed in contract.
3. Water column samples from locations described above, including QA/QC samples, as listed in Contract, delivered to laboratory selected by UDWQ per sampling protocol.
4. Turbidimeter and thermistor data sets.
5. Progress updates in the form of data graphs and statistical summaries will be provided to UDWQ or designee upon demand. Data requests cannot exceed 2 requests per 12-month study period.
6. Preliminary report summarizing selenium burdens on macromolecular to particulate size fractions with identification of phase (mineral versus biological) in the water column and sediment trap samples and turbidity and temperature gradients relative to storm events. The report will provide a very preliminary estimated of the annual net downward and re-intrainment of selenium. The objective of this report is to provide the Science Panel with available information gathered in 2006-2007. Preliminary report will be completed by 03/31/2007.
7. Final report on estimate of annual net downward particulate flux rate of selenium to the littoral sediment and deep brine layer and estimate of annual sediment re-entrainment/selenium resolubilization following storm events. Report will document activities, methods, assumptions, data, recommendations, and conclusions completed as part of this task (completed by 8/31/2007).

Task 3 – Solid-Phase Sampling and Development of Overall Selenium Budget

Objective

The collection and analysis of cores will support determination of selenium burial rates, as well as determination of potential re-introduction of selenium to the water column in response to lake level change.

Task Schedule

	CY 2006				CY 2007				2008
Task 3	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**
Preparation for box coring and lake-bed sampling									
Coring across E-W transect									
Dry lake bed sampling									
Sequential extractions of box core samples									
Synthetic precipitation leaching of lake-bed samples									
Selenium analysis of extracts and leachates									
Final report--selenium budget including results from Projects 3 and 4									

Task 3.1 Assess Se burial rate

Replicate 20-cm cores will be taken from three locations (one under Deep Brine Layer) to support determination of selenium burial rate. One core from each of the three locations will be dated (^{137}Cs at 8 depths per core) to support determination of selenium concentration as a funtion of depth (burial rate). The other core from each location will be analyzed for elemental makeup and Se as a function of depth (8-10 depths) using both HG-AA for total Se and FFF-ICP-MS for elemental makeup. Se will be normalized to Cs or Al (which are less bioactive) to differentiate post depositional remobilization from change in selenium deposition flux. The selenium burden on macromolecular to particulate phases (via FFF-ICP-MS) will be compared to sediment trap results to assess the significance of chemical changes after burial.

Task 3.2 Collect submerged sediment samples

Core transect across Gilbert Bay from Farmington Bay causeway to west shore, including sediment samples underlying deep brine (anoxic) and upper brine (oxic). Because of the anoxic conditions present in the Deep Brine Layer, it is possible that the solid-phase selenium pool in these sediments may be higher relative to sediments beneath the oxic Upper Brine Layer. Twenty cores will be collected along this transect.

Task 3.3 Determine Re-solubilization Potential of Submerged Sediment

Sequential extraction from the twenty submerged cores will be performed to determine re-solubilization potential under changing lake conditions. Previous work on GSL has shown that the spatial extent of the Deep Brine Layer changes under different hydrologic conditions. Because of the anoxic conditions associated with the Deep Brine Layer, the sediments in these areas may have enriched selenium concentrations relative to other parts of GSL. Operationally defined sequential extractions of sediment underlying both the Deep and Upper Brine Layers will be conducted to provide an estimate of potential selenium release under future hydrologic regimes in GSL. Sequential extractions will be performed at the

University of Utah and analyzed via HG-AA and/or ICP-MS depending on applicability of ICP-MS to analysis of resulting extract.

Task 3.4 Determine Solubilizaton Potential of Exposed Sediment

Measure batch solubilization of selenium from exposed lake bed sediment samples. Thirty suface samples (0 to 0.5 ft sample depth) from exposed lake bed sediments will be collected. To minimize small-scale sample variability, each sample will be composited from 10 samples within a 40 ft radius of the the initial sample site. Each sample will be collected with a stainless steel spoon and samples will be composited in a stainless steel mixing bowl. After mixing, a sample composite will be placed in double plastic bag until sample extraction and analysis. Between each sample site, a wire brush will be used to remove sediment from the sampling spoon and bowl. After brushing, the sampling equipment will be sprayed with DI water and air dried. Sampling equipment will be placed in plastic bags and sealed before transport to the next sampling site. Each sediment sample will be extracted using synthetic precipitation leach protocol (USEPA method 1312). Sequential extractions will be performed at the University of Utah and analyzed via HG-AA and/or ICP-MS depending on applicability of ICP-MS to analysis of resulting extract.

Fifty samples (20 submerged cores and 30 surface samples) will undergo extractions. Assuming that three sequential extractions (three progressively stronger extractants) will be performed on each sample, the total number of analyses is 150 via HG-AA. Alternatively, initial results may indicate that it is unnecessary to perform three extractions on all samples, and that additional elemental information would be more beneficial to this task. In this case, ICP-MS can be employed (more expensive than HG-AA). Hence, the 150 analyses is a placeholder for a yet-to be determined mix of sequential extractions and elemental characterization.

Task 3.5 Calculate Se Load for Given Lake Rise

Calculate selenium load for given lake rise. Area volume data for GSL that are now available from USGS, provide detailed information on the acres of exposed sediment that will be flooded for each 0.5 feet rise in lake elevation. Results from the USEPA synthetic precipitation leaching protocol (Task 3.4) will be combined with the available area/volume data to estimate annual selenium loads that may be expected from annual lake shore flooding scenarios. These scenarios will be based on past rates of lake elevation changes available from long-term USGS lake-level monitoring stations. Shoreline selenium loadings will be compared to riverine selenium loadings determined from project 3.

Task 3.6 Develop Overall Se Budget

Develop overall selenium budget combining data collected from Projects 3 and 4. The selenium budget will be presented in spreadsheet or STELLA-type format for ease of utilization by UDWQ, after consultation with UDWQ.

Deliverables:

1. Six 20-cm sediment cores. Three cores will be dated. Results of analysis of the other three cores for elemental makeup and Se as a function of depth.
2. Twenty submerged cores from transect (Task 3.1).

3. Data from sequential extractions of twenty submerged sediment cores.
4. Thirty sediment samples of exposed sediment. Data from sequential extractions of these samples.
5. Progress updates in the form of data graphs and statistical summaries will be provided to UDWQ or designee upon demand. Data requests cannot exceed 2 requests per 12-month study period.
6. Preliminary report on selenium yield during sequential extraction from exposed and submerged sediment cores (Tasks 3.3 and 3.4). Report will document activities, methods, assumptions, data, recommendations, and conclusions completed as part of this task (completed by 03/31/2007).
7. Preliminary estimate of selenium loads to GSL from resaturation of dry lake bed and estimated re-solubilization potential of selenium from submerged cores due to changes in extent of deep brine layer (completed by 03/31/07).
8. Final report on overall selenium budget incorporating estimated selenium fluxes due to external loading; vaporization; sedimentation; and resolubilization-precipitation due to lake area change. Report will document activities, methods, assumptions, data, recommendations, and conclusions completed as part of this task (completed by 3/31/2008).

FIGURE 1
Sampling Locations For Total Dissolved Gas